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NEURORADIOLOGY

INVITED COMMENTARY



# Standardizing neuroradiological ancillary testing in brain death determination: a national clinical protocol from Türkiye

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**ABSTRACT**

This commentary introduces Türkiye's national clinical protocol for neuroradiological ancillary testing in brain death determination, which was developed to address persistent variability in imaging-based practice; it was first published in Turkish (2025) and subsequently translated into English (2026). It outlines a pragmatic national framework for the standardized use, interpretation, and reporting of computed tomography angiography, digital subtraction angiography, and transcranial Doppler ultrasonography while reaffirming that brain death remains a clinical diagnosis. By emphasizing practical examples, structured reporting, common pitfalls, and pediatric considerations, the protocol aims to improve consistency and interpretive reliability while contributing to the broader international discussion on ancillary testing.

**KEYWORDS**

Brain death, death by neurologic criteria, ancillary testing, computed tomography angiography, neuroradiology, clinical guidelines, pediatric brain death

The determination of death by neurologic criteria (DNC), commonly referred to as brain death, is fundamentally a clinical diagnosis based on the irreversible cessation of all brain functions.[1,2] Ancillary tests for diagnosis are not intended to replace the clinical examination, although they are often used in specific circumstances.[1] These include situations where the clinical examination is confounded by severe craniofacial trauma, pre-existing ocular or cranial nerve abnormalities, or when the apnea test cannot be safely performed due to hemodynamic instability or severe hypoxemia. Furthermore, ancillary tests are utilized to facilitate timely diagnosis when legal requirements necessitate a single clinical examination followed by a confirmatory objective test. Despite broad agreement on these principles, the type, role, and interpretation of ancillary tests, particularly imaging-based methods, vary substantially across countries and guidelines.[2,3]

In response to this variability, the Republic of Türkiye Ministry of Health released the Clinical Protocol for Neuroradiological Diagnostic Criteria in Brain Death in Turkish in 2025 and in English in 2026.[4,5] The protocols can also be accessed through the following link: https://osf.io/fej34/overview. The protocol was developed through a structured review of the literature and a series of regularly scheduled multidisciplinary meetings involving the authors, with participation from representatives of the Ministry of Health. The protocol was originally prepared in the Turkish language to support national implementation and was subsequently translated into English to facilitate broader international accessibility and knowledge sharing. It was developed within the framework of the National Organ Transplantation and Donation Coordination System and reviewed by the Turkish Society of Radiology. It primarily aims to standardize neuroradiological ancillary testing practices at a national level.

This commentary summarizes the scope, rationale, and structure of the protocol, situating it within the broader international context while staying within the evidence base on which it is founded.

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## Rationale for a neuroradiology-focused protocol

Although international consensus documents have clarified many aspects of DNC determination, neuroradiological ancillary tests remain an area of persistent heterogeneity.[2,3] Differences are evident in (i) which imaging modalities are accepted, (ii) how they should be performed, and (iii) which radiological criteria should be used for interpretation. Computed tomography angiography (CTA), for example, is recommended as a standard ancillary test in some countries,[6] whereas current United States guidelines cite insufficient evidence to recommend its use.[7] A simplified comparative overview of prominent international guideline approaches to ancillary neuroradiological testing is summarized in Table 1.

Within Türkiye, as in many healthcare systems, CTA, digital subtraction angiography (DSA), and transcranial Doppler ultrasonography (TCD) are widely available and frequently used in practice. Before this protocol, however, uniform imaging acquisition parameters, interpretation criteria, and reporting standards were not formally defined at the national level. The protocol, therefore, focuses not on endorsing a single modality but on standardizing how commonly used neuroradiological tests are applied and interpreted when used as ancillary support to a clinical diagnosis of brain death.

## Scope and general principles

The protocol explicitly reaffirms that brain death is a clinical diagnosis, consistent with national legislation. Neuroradiological tests are positioned as supportive tools rather than confirmatory substitutes. Importantly, the document avoids ranking ancillary tests or mandating a preferred modality. Instead, test selection is left to institutional resources, patient-specific factors, and clinical judgment.

The scope is limited to neuroradiological imaging methods. Nuclear medicine techniques and electroencephalography are intentionally excluded, reflecting both practical considerations and the protocol's focus on radiological workflows. Separate sections address adult and pediatric populations, recognizing the substantial physiological and anatomical differences that influence imaging interpretation.

A distinguishing characteristic of the protocol is its deliberate emphasis on practical interpretation, supported by numerous illustrative case examples and an explicit discussion of common pitfalls. This case-based approach is intended to complement existing guideline documents, many of which primarily focus on high-level recommendations and provide limited guidance on real-world imaging interpretation challenges.

## Adult neuroradiological ancillary tests

### *Digital subtraction angiography*

DSA is formally presented as a reference or gold standard ancillary neuroradiological method. This designation is based on the modality's ability to provide a definitive demonstration of the arrest of cerebral blood flow at a certain level. The protocol provides detailed guidance on catheterization strategies, contrast volumes, acquisition duration, and minimum imaging requirements. Interpretation criteria emphasize the absence of antegrade intracranial arterial flow and the lack of venous drainage. Potential sources of false-negative results, such as insufficient intracranial pressure elevation or stasis filling, are explicitly discussed.

### *Transcranial Doppler ultrasonography*

TCD is described as a noninvasive option for adult patients when performed by experienced operators. The protocol standardizes insonation windows, hemodynamic prerequisites, and waveform interpretation. Diagnostic patterns, such as oscillatory flow, systolic spikes, and complete flow absence, are defined, alongside common pitfalls, including decompressive craniectomy, preserved collateral circulation, and systemic hypotension.

### *Computed tomography angiography*

CTA receives particular attention due to its widespread availability and variable international acceptance. Rather than proposing new criteria, the protocol adopts previously published CTA scoring systems, with emphasis on the 4-point scale assessing bilateral cortical middle cerebral artery branches (M4) and internal cerebral veins.[8] Acquisition timing, contrast dosing, and interpretation steps are specified in detail to minimize technical and interpretative variability.

In short, the examination requires adequate physiologic conditions, including a confirmed mean arterial pressure >60 mmHg and a body temperature >35°C, together with the administration of non-ionic iodinated contrast material (100–120 mL in adults; 1–2 mL/kg in children) with a minimum iodine concentration of 340 mg/mL. A three-phase acquisition is mandated: (i) a non-contrast phase, to identify pre-existing hyperdensities (e.g., previous contrast, thrombosis) that could lead to false-negative interpretations; (ii) an early phase (20 s), used

**Table 1.** Simplified comparative overview of major international guideline approaches to ancillary neuroradiological testing

| Guideline/protocol | Year | DSA | CTA | TCD |
|---|---|---|---|---|
| Republic of Türkiye (Ministry of Health Clinical Protocol)[4,5] | 2025 | **Accepted** | **Accepted.** Focuses on 4-point scoring system (M4 + ICV) | **Accepted (adults only)** |
| United Kingdom Consensus Guideline[6] | 2023 | - | **Preferred.** Accepted as a standard ancillary investigation for adults | - |
| Canada Clinical Practice Guideline[9] | 2023 | **Not recommended** | **Accepted (adults only).** 10-point scoring system discussed | **Accepted (adults only)** |
| American Academy of Neurology; American Academy of Pediatrics[7] | 2023 | **Accepted** | **Not recommended** | **Accepted (adults only)** |
| World Brain Death Project[10] | 2020 | **Accepted** | **Not recommended** | **Accepted (adults only)** |

CTA, computed tomography angiography; DSA, digital subtraction angiography; ICV, internal cerebral vein; M4, cortical segment of the middle cerebral artery; TCD, transcranial Doppler ultrasound.

**Note #1:** "Accepted" denotes acceptance as an ancillary test rather than as a primary diagnostic test or a preferred method.

**Note #2:** This table does not encompass the nuanced, age-specific pediatric recommendations within each framework. As diagnostic criteria in children vary substantially according to patient age and cranial development (e.g., status of fontanelles and sutures), readers are advised to consult the specific pediatric sections of the referenced guidelines or the Türkiye protocol.[4,5]

exclusively to confirm successful contrast delivery by visualizing opacification of the superficial temporal arteries; and (iii) a delayed phase (60 s), the definitive phase for assessing the intracranial vascular opacification.

The protocol places special emphasis on side-by-side comparison of non-contrast and 60-s post-contrast images, supported by multiple example cases demonstrating both supportive and non-supportive findings. The diagnosis of brain death can be supported only if there is a complete absence of contrast opacification in all four vessels (i.e., M4 and internal cerebral veins). Conversely, the presence of contrast in any of these four landmarks does not support the diagnosis.

An example of a CTA assessment for suspected brain death is provided in Figure 1. For more detailed evaluation guidance and a wide range of practical example cases, readers are referred to the full protocol.[4,5]

## Pediatric considerations

Ancillary testing in children presents additional challenges due to open sutures and fontanelles, which can prevent the rise in intracranial pressure required to arrest cerebral blood flow. The protocol acknowledges the limited pediatric evidence base and the absence of international consensus, explicitly cautioning against the direct application of adult criteria to children.

Both CTA and DSA are discussed cautiously, recognizing that adult-derived CTA scoring systems may yield false-negative results in pediatric patients; persistent, non-functional perfusion may be observed even when clinical criteria for brain death are met. Where CTA is used, the protocol highlights the potential value of supplemental venous assessment, including superior petrosal veins, as supportive rather than definitive findings. The pediatric section includes numerous case examples illustrating scenarios in which perfusion may remain preserved despite severe injury, thereby reducing the risk of misinterpretation.

## Reporting templates and standardization

A distinctive feature of the protocol is the inclusion of structured reporting templates for each imaging modality. These templates are designed to (i) ensure documentation of technical adequacy, (ii) standardize terminology, and (iii) clearly separate descriptive findings from interpretive conclusions. Reports are limited to stating whether imaging findings support or do not support the clinical diagnosis of brain death, avoiding absolute or determinative language. A brief reporting template example for CTA is provided in Box 1. For detailed reporting templates for all modalities, readers are referred to the full protocol.[4,5]

## Strengths and limitations

The primary strength of this protocol lies in its pragmatic standardization of imaging practice, supported by detailed protocols, checklists, and a substantial collection of illustrative cases. By explicitly addressing pitfalls and sources of misinterpretation, it aims to complement existing guidelines that may offer limited practical imaging guidance.

At the same time, the protocol does not attempt to resolve international disagreements regarding ancillary testing, nor does it propose new diagnostic criteria. Its limitations include reliance on heterogeneous and, in some areas, limited evidence, particularly within pediatric populations.

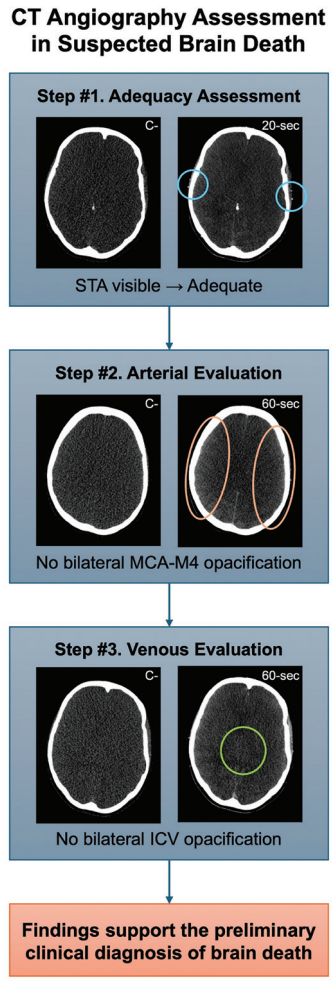


**Figure 1.** Computed tomography angiography (CTA) assessment example in suspected brain death, according to the 4-point system. Adequate scan quality is confirmed by visualization of the superficial temporal artery (STA; blue circles). Absence of opacification in the bilateral middle cerebral artery (MCA) cortical (M4) branches (orange ellipses) and bilateral internal cerebral veins (ICVs; green circle) supports the preliminary clinical diagnosis of brain death.

**Box 1.** Concise reporting template example

**Examination:** Computed tomography angiography for brain death determination.

**Clinical information:** [age]-year-old patient with a history of [relevant condition or event]; apnea test [positive/could not be performed].

**Technique:** Non-contrast phase followed by early (20 s) and delayed (60 s) post-contrast phases after intravenous administration of non-ionic iodinated contrast material (100 mL; iodine concentration 340 mg/mL).

**Findings:**
- **Quality check:** Opacification of the superficial temporal arteries confirmed on the 20-s phase, indicating successful contrast delivery.
- **Intracranial vascular evaluation (60-s phase):**
  - **M4 segments of right MCA:** [Opacified/not opacified]
  - **M4 segments of left MCA:** [Opacified/not opacified]
  - **Right internal cerebral vein:** [Opacified/not opacified]
  - **Left internal cerebral vein:** [Opacified/not opacified]

**Impression:**
- [Choice A]: Findings **SUPPORT** the clinical diagnosis of brain death (complete absence of opacification in the 4-point landmarks).
- [Choice B]: Findings **DO NOT SUPPORT** the clinical diagnosis of brain death (persistence of opacification in one or more landmarks).

**MCA,** middle cerebral artery.

## Final remarks

This national clinical protocol represents an effort to operationalize neuroradiological ancillary testing within a clearly defined clinical and legal framework while maintaining consistency with international evidence. By combining standardized imaging protocols with extensive case-based illustration, it seeks to support accurate interpretation in routine clinical practice.

The protocol is intended as a living document, adaptable to future evidence and evolving international standards. Its contribution lies not in redefining brain death criteria but in providing a transparent and reproducible approach to neuroradiological support of a fundamentally clinical diagnosis.


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## Footnotes

## Conflict of interest disclosure

All co-authors are also authors of the clinical protocol that is the subject of this commentary. Burak Kocak, MD, served as Section Editor for Diagnostic and Interventional Radiology (Section: Artificial Intelligence and Informatics; 2023-2025) during the conduct of this commentary. He had no involvement in the peer-review of this article and had no access to information regarding its peer-review.

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